NUWC-NPT Technical Document 11,119
26 April 1996

Impedance Measurements of Loctite Silicone Rubber and Structural Damping Results of Mold-Ex Silicone MX-111

Andrew J. Hull
Submarine Sonar Department

Rolf G. Kasper
Engineering and Technical Services Department

Naval Undersea Warfare Center Division
Newport, Rhode Island

Approved for public release; distribution is unlimited.

PREFACE

The research in this document was performed under a Cooperative Research and Development Agreement (CRADA) between the Naval Undersea Warfare Center (NUWC) Detachment, New London, Connecticut, and the Loctite Corporation, Rocky Hill, Connecticut.

The authors wish to thank Dr. Stephen Austin, formerly of NUWC Detachment New London and presently with Heidelberg-Harris, Inc., in Dover, New Hampshire, for coordinating and planning the air tube acoustic tests on behalf of the Loctite Corporation. Appreciation is also extended to Dr. Robert Lafreniere and Wendell Maciejewski of NUWC Detachment New London and Roger Tryon of McLaughlin Research Corporation for their assistance with the dynamic structural tests performed on the Metravib Viscoanalyzer. Finally, Richard Thompson and his associates at Loctite are to be acknowledged for their helpfulness and cooperation during the course of this experiment.

Reviewed and Approved: 26 April 1996

Russell L. Brown

R. L. Brown
Head, Engineering and Technical Services Department

R J Martin

R. J. Martin
Acting Head, Submarine Sonar Department

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	26 April 1996	Final

4. TITLE AND SUBTITLE

Impedance Measurements of Loctite Silicone Rubber and Structural Damping Results of Mold-Ex Silicone MX-111

5. FUNDING NUMBERS

6. AUTHOR(S)

Andrew J. Hull and Rolf G. Kasper

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Undersea Warfare Center
Detachment New London
New London, Connecticut 06320

8. PERFORMING ORGANIZATION REPORT NUMBER

TD 11,119

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The research in this document was performed under a Cooperative Research and Development Agreement (CRADA) between the Naval Undersea Warfare Center Detachment, New London, Connecticut, and the Loctite Corporation, Rocky Hill, Connecticut.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

On 5 December 1995, the Naval Undersea Warfare Center (NUWC) Detachment in New London, Connecticut, and the Loctite Corporation in Rocky Hill, Connecticut, signed a Cooperative Research and Development Agreement (CRADA). The CRADA required that the NUWC detachment perform a number of acoustic impedance tests in their New London calibrated air tube facility. Loctite provided specimens of standard silicone rubber and silicone rubber embedded with iron powder and glass microbeads, both of which were especially prepared for the air tube facility. A number of tests were run at several different thicknesses to determine acoustic impedance properties. From these measurements, it was concluded that both specimens respond identically to a plane acoustic air wave. Furthermore, each specimen almost totally reflects this wave and its corresponding acoustic impedance is nearly infinite. In a second set of tests (not sponsored by the CRADA), structural strength and damping data were obtained from analyses conducted on the Mold-Ex silicone MX-111 material with the Metravib-Viscoanalyzer.

14. SUBJECT TERMS

Acoustic Impedance Measurements, Air Tube Acoustic Test, Airborne Test, Dynamic Structural Testing, Loss Mechanism, Marine Structure, Silicone Rubber, Structural Damping

15. NUMBER OF PAGES

62

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

IMPEDANCE MEASUREMENTS OF LOCTITE SILICONE RUBBER AND STRUCTURAL DAMPING RESULTS OF MOLD-EX SILICONE MX-111

INTRODUCTION

On 5 December 1995, the Naval Undersea Warfare Center (NUWC) Detachment in New London, Connecticut, and the Loctite Corporation signed a Cooperative Research and Development Agreement (CRADA). The CRADA required that the NUWC detachment perform a number of acoustic impedance tests in their New London calibrated air tube facility. Loctite provided specimens of standard silicone rubber and silicone rubber embedded with iron powder and glass microbeads, both of which were especially prepared for the air tube facility. A number tests were run at several different thicknesses to determine acoustic impedance properties. The results of these tests are discussed in the first section of this document. The second section contains structural strength and damping results from analyses conducted on the Mold-Ex silicone MX-111 material with the Metravib-Viscoanalyzer.

IMPEDANCE MEASUREMENTS OF LOCTITE SILICONE RUBBER SAMPLES

From these measurements, it was determined that both the standard silicone rubber and the silicone rubber with embedded iron powder and glass microbeads respond identically to a plane acoustic air wave. Furthermore, each specimen almost totally reflects this wave and its corresponding acoustic impedance is nearly infinite.

Six pieces of silicone rubber were received in December 1995 for acoustic impedance testing in the New London air tube facility. Three were control pieces made of standard silicone rubber (the red pieces) and three were silicone rubber with embedded iron powder and glass microbeads (the black pieces). Three material thicknesses were tested for the 0.191-diameter plastic-backed sample: 2, 4, and 6 mm. Each specimen was inserted into the end of the air tube with the material positioned in such a manner that its face was exposed to the plane wave generated at the speaker, as shown in figure 1. The length of the air tube was 6.026 m and the distance from the speaker to the domain measurement microphone was 2.902 m.

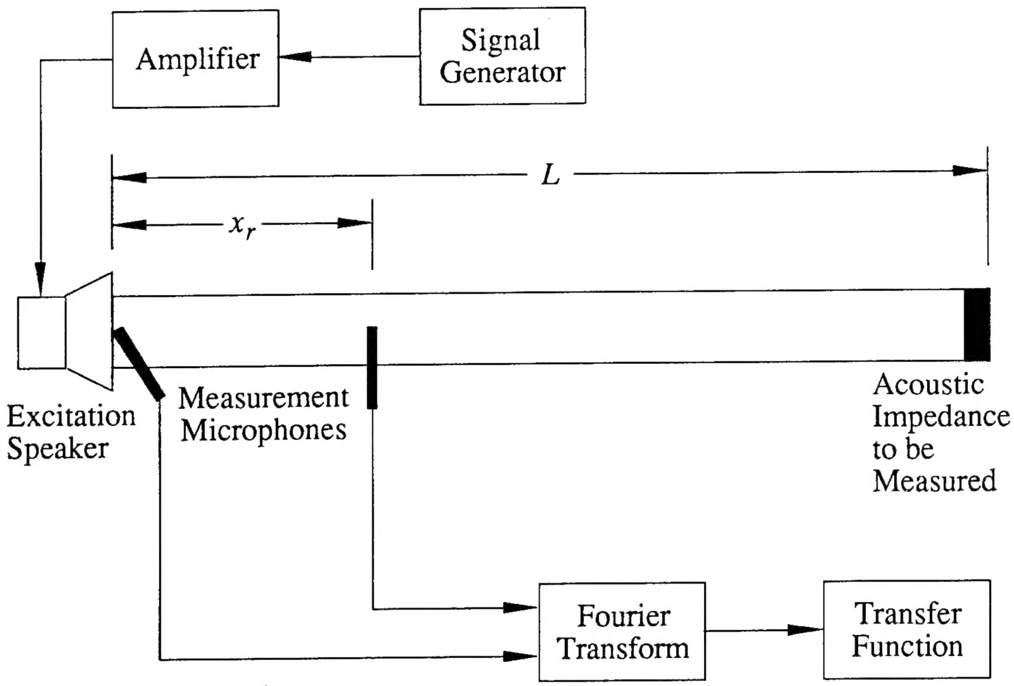


Figure 1. The Laboratory Configuration

Tables 1 and 2 contain the data from the 2-mm samples, tables 3 and 4 from the 4-mm samples, and tables 5 and 6 from the 6-mm samples. Figures 2, 3, and 4 are plots of the measured transfer functions for the 2-, 4-, and 6-mm samples, respectively. In each figure, the solid lines are the silicone rubber with embedded iron powder and glass microbeads and the dashed lines are the standard silicone rubber. Since the transfer functions of both materials are seen to be nearly identical, it was concluded that the acoustic impedance of both samples (responding to an airborne plane wave) is the same. Additionally, when figures 2, 3, and 4 are superimposed on one another, it becomes apparent that the thickness of the material has no effect on the acoustic impedance.

Table 7 provides the first 17 eigenvalues of the transfer function. These eigenvalues were extracted using the curve-fitting routine on the HP3562 dynamic signal analyzer. Although the transfer function from figure 1 was used to determine these eigenvalues, any other figure would produce very similar ones. Acoustic impedance can be determined directly from the eigenvalues.

At this point, it is important to understand the basic theory of measuring acoustic impedance. For the test to be successful, the loss mechanism of the material inserted into the end of the duct must be moderately larger than the loss mechanism of both the duct itself and the speaker end. In generating the theory, the duct and excitation end are considered lossless. However, in reality,

they are not. Thus, when a material is placed in the end of a duct that does not have a significant loss mechanism, the theoretical equations used to determine acoustic impedance tend to incorrectly "lump" all the loss mechanisms of the system into the acoustic impedance of the sample, which produces an incorrect measurement value.

The low loss situation is occurring for all the samples tested. Although this phenomenon can be explained with a number of methods, the best approach examines the real part of the eigenvalues, which has a value around or below $|0.5|$. This low value indicates an extremely low loss system that includes both the sample and the duct. Any calculations of the acoustic impedance would contain large errors. However, this low loss condition definitively shows that the materials tested are reflecting nearly all the airborne acoustic energy and that their corresponding acoustic impedance is nearly infinity. Thus, this material is behaving much like a metal (such as aluminum or steel) would behave for the same type of experiment. If the system did have significant attenuation characteristics, the phase angle of the data would begin approaching a straight line and the resonant peaks of the magnitudes would be lower and wider.

This impedance test does have some limitations. The characteristic impedance of the tube is defined as the density multiplied by the wave speed (ρc). Because the tube is air filled, its specific impedance is very low, resulting in an experiment that cannot differentiate one large end impedance from another. For example, this experiment would not be able to differentiate between the responses of urethane and a stiffer material, such as steel, to an airborne acoustic wave. Furthermore, if these materials were to be used in an underwater application, the test should be run with water as the transmission medium in the impedance tube.* This would produce a much larger characteristic impedance, and the mismatch between the impedance of the tube and that of the sample would be significantly smaller than for the air-filled tube described above. Although the difference between the silicone rubber samples might or might not be apparent in the water-filled tube data, for acoustic applications in air-filled environments, the testing conducted here is sufficient to determine the acoustic response of each material.

* NUWC Detachment New London does not have a water-filled impedance tube.

Table 1. Transfer Function of 2-mm-Thick Standard Silicone Rubber

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
0.0	0.813	0.000	-1.80	0.0
5.0	1.122	0.002	1.00	0.1
10.0	1.335	0.069	2.52	3.0
15.0	-2.393	-2.634	11.03	-132.3
20.0	-0.723	-0.057	-2.80	-175.5
25.0	-0.163	-0.033	-15.56	-168.5
30.0	0.133	-0.036	-17.22	-15.3
35.0	0.514	-0.058	-5.72	-6.5
40.0	1.788	-0.256	5.13	-8.2
45.0	-4.108	-0.545	12.35	-172.4
50.0	-1.415	-0.067	3.02	-177.3
55.0	-1.053	-0.014	0.45	-179.2
60.0	-1.004	0.004	0.04	179.8
65.0	-1.220	0.035	1.73	178.4
70.0	-2.980	0.568	9.64	169.2
75.0	1.335	0.336	2.78	14.1
80.0	0.194	0.045	-14.01	13.1
85.0	-0.126	0.031	-17.73	166.1
90.0	-0.435	0.032	-7.21	175.8
95.0	-1.057	0.069	0.50	176.3
100.0	-5.407	3.616	16.26	146.2
105.0	2.381	0.328	7.62	7.8
110.0	1.205	0.042	1.62	2.0
115.0	0.977	0.009	-0.20	0.5
120.0	0.978	-0.002	-0.19	-0.1
125.0	1.328	-0.041	2.47	-1.8
130.0	-2.040	-6.368	16.50	-107.8
135.0	-0.330	-0.085	-9.35	-165.5
140.0	0.132	-0.039	-17.24	-16.4
145.0	0.403	-0.038	-7.85	-5.4
150.0	0.779	-0.064	-2.14	-4.7
155.0	1.942	-0.163	5.80	-4.8
160.0	-6.068	-2.448	16.32	-158.0
165.0	-1.638	-0.092	4.30	-176.8
170.0	-1.044	-0.022	0.38	-178.8
175.0	-0.889	-0.009	-1.02	-179.4
180.0	-0.941	0.009	-0.53	179.5
185.0	-1.586	0.177	4.06	173.6
190.0	0.609	0.248	-3.64	22.2
195.0	-0.162	0.046	-15.44	164.1
200.0	-0.394	0.036	-8.05	174.7
205.0	-0.653	0.038	-3.69	176.6
210.0	-1.239	0.060	1.87	177.2
215.0	-5.410	1.333	14.92	166.2
220.0	2.701	0.219	8.66	4.6
225.0	1.212	0.043	1.68	2.0
230.0	0.880	0.015	-1.11	1.0
235.0	0.775	0.009	-2.21	0.6
240.0	0.842	-0.014	-1.50	-0.9
245.0	1.438	-1.783	7.20	-51.1
250.0	0.205	-0.052	-13.50	-14.3
255.0	0.428	-0.030	-7.36	-4.0

Table 1. Transfer Function of 2-mm-Thick Standard Silicone Rubber (Cont'd)

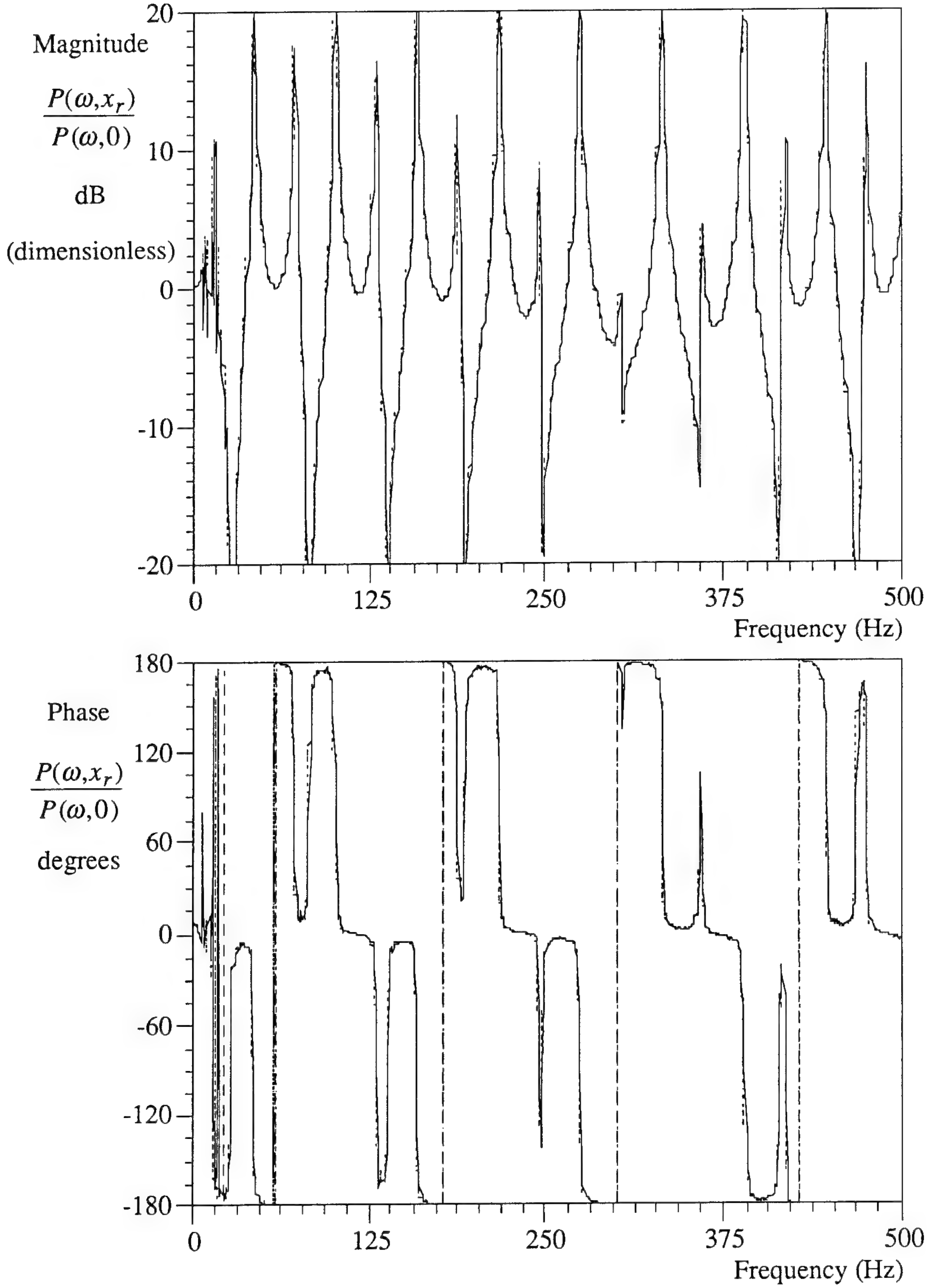
Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
260.0	0.615	-0.029	-4.22	-2.7
265.0	0.951	-0.058	-0.42	-3.5
270.0	2.101	-0.252	6.51	-6.9
275.0	-6.157	-5.141	18.08	-140.1
280.0	-1.669	-0.162	4.49	-174.5
285.0	-0.955	-0.045	-0.39	-177.3
290.0	-0.728	-0.022	-2.75	-178.3
295.0	-0.623	-0.014	-4.11	-178.7
300.0	-0.625	-0.005	-4.08	-179.6
305.0	-0.395	0.043	-8.02	173.7
310.0	-0.522	0.019	-5.63	177.9
315.0	-0.623	0.021	-4.10	178.1
320.0	-0.834	0.030	-1.57	177.9
325.0	-1.343	0.072	2.58	176.9
330.0	-3.928	1.143	12.24	163.8
335.0	3.115	0.451	9.96	8.2
340.0	1.160	0.058	1.30	2.9
345.0	0.729	0.032	-2.73	2.5
350.0	0.525	0.027	-5.58	2.9
355.0	0.368	0.033	-8.65	5.1
360.0	-0.197	0.665	-3.18	106.5
365.0	0.780	0.005	-2.16	0.4
370.0	0.711	-0.009	-2.97	-0.7
375.0	0.803	-0.017	-1.90	-1.2
380.0	1.075	-0.063	0.65	-3.4
385.0	2.010	-0.218	6.12	-6.2
390.0	-3.028	-9.936	20.33	-107.0
395.0	-1.685	-0.178	4.58	-174.0
400.0	-0.826	-0.062	-1.64	-175.7
405.0	-0.506	-0.040	-5.90	-175.5
410.0	-0.302	-0.039	-10.33	-172.6
415.0	0.099	-0.103	-16.90	-45.9
420.0	-2.033	-0.567	6.49	-164.4
425.0	-0.909	-0.010	-0.82	-179.4
430.0	-0.836	0.006	-1.55	179.6
435.0	-0.954	0.029	-0.40	178.3
440.0	-1.379	0.075	2.81	176.9
445.0	-3.083	0.775	10.05	165.9
450.0	3.076	0.757	10.01	13.8
455.0	1.013	0.096	0.15	5.4
460.0	0.525	0.040	-5.57	4.4
465.0	0.263	0.035	-11.52	7.5
470.0	-0.080	0.054	-20.32	146.1
475.0	-1.463	1.106	5.27	142.9
480.0	1.473	0.109	3.39	4.2
485.0	0.974	0.017	-0.22	1.0
490.0	0.934	-0.008	-0.59	-0.5
495.0	1.113	-0.042	0.94	-2.2
500.0	1.834	-0.164	5.30	-5.1

Table 2. Transfer Function of 2-mm-Thick Silicone Rubber With Embedded Iron Powder and Glass Microbeads

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
0.0	0.602	0.000	-4.41	0.0
5.0	1.120	0.012	0.99	0.6
10.0	0.810	0.140	-1.70	9.8
15.0	-1.954	-2.310	9.62	-130.2
20.0	-0.632	-0.078	-3.91	-172.9
25.0	-0.176	-0.030	-14.98	-170.4
30.0	0.139	-0.039	-16.82	-15.6
35.0	0.532	-0.064	-5.42	-6.8
40.0	1.861	-0.381	5.57	-11.6
45.0	-4.177	-1.112	12.71	-165.1
50.0	-1.438	-0.043	3.16	-178.3
55.0	-1.048	-0.011	0.41	-179.4
60.0	-1.005	0.004	0.04	179.8
65.0	-1.233	0.018	1.82	179.1
70.0	-2.706	0.258	8.69	174.6
75.0	1.295	0.208	2.35	9.1
80.0	0.211	0.063	-13.13	16.6
85.0	-0.129	0.038	-17.43	163.4
90.0	-0.434	0.040	-7.21	174.8
95.0	-1.049	0.057	0.43	176.9
100.0	-5.436	3.655	16.33	146.1
105.0	2.270	0.290	7.19	7.3
110.0	1.227	0.035	1.78	1.7
115.0	0.978	0.011	-0.19	0.7
120.0	0.980	-0.002	-0.18	-0.1
125.0	1.350	-0.079	2.62	-3.3
130.0	-0.044	-6.293	15.98	-90.4
135.0	-0.314	-0.100	-9.63	-162.4
140.0	0.137	-0.034	-16.99	-13.9
145.0	0.399	-0.045	-7.93	-6.5
150.0	0.757	-0.077	-2.37	-5.8
155.0	1.897	-0.216	5.61	-6.5
160.0	-5.887	-2.396	16.06	-157.9
165.0	-1.603	-0.129	4.13	-175.4
170.0	-1.038	-0.028	0.32	-178.5
175.0	-0.892	-0.009	-1.00	-179.5
180.0	-0.937	0.006	-0.56	179.6
185.0	-1.537	0.187	3.80	173.1
190.0	0.690	0.267	-2.61	21.1
195.0	-0.149	0.041	-16.22	164.5
200.0	-0.394	0.033	-8.05	175.2
205.0	-0.653	0.062	-3.66	174.6
210.0	-1.229	0.079	1.81	176.3
215.0	-5.331	1.344	14.80	165.8
220.0	2.574	0.436	8.33	9.6
225.0	1.230	0.056	1.81	2.6
230.0	0.882	0.020	-1.09	1.3
235.0	0.776	0.009	-2.20	0.6
240.0	0.853	-0.007	-1.38	-0.5
245.0	1.730	-1.923	8.26	-48.0
250.0	0.194	-0.052	-13.96	-14.9
255.0	0.425	-0.028	-7.41	-3.7

Table 2. Transfer Function of 2-mm-Thick Silicone Rubber With Embedded Iron Powder and Glass Microbeads (Cont'd)

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
260.0	0.611	-0.031	-4.26	-2.9
265.0	0.977	-0.069	-0.18	-4.0
270.0	2.050	-0.311	6.33	-8.6
275.0	-7.236	-5.533	19.19	-142.6
280.0	-1.718	-0.186	4.75	-173.8
285.0	-0.956	-0.052	-0.38	-176.9
290.0	-0.723	-0.018	-2.82	-178.6
295.0	-0.625	-0.015	-4.08	-178.6
300.0	-0.639	-0.009	-3.89	-179.2
305.0	-0.378	0.061	-8.33	170.8
310.0	-0.517	0.017	-5.73	178.1
315.0	-0.626	0.022	-4.06	178.0
320.0	-0.823	0.038	-1.68	177.4
325.0	-1.345	0.072	2.59	177.0
330.0	-3.840	0.932	11.94	166.4
335.0	2.954	0.606	9.59	11.6
340.0	1.155	0.068	1.26	3.4
345.0	0.736	0.032	-2.66	2.5
350.0	0.525	0.022	-5.59	2.4
355.0	0.353	0.038	-8.98	6.1
360.0	-0.111	0.901	-0.84	97.1
365.0	0.775	0.012	-2.21	0.9
370.0	0.710	-0.009	-2.98	-0.7
375.0	0.798	-0.020	-1.96	-1.4
380.0	1.061	-0.064	0.53	-3.4
385.0	1.981	-0.245	6.01	-7.0
390.0	0.402	-9.352	19.43	-87.5
395.0	-1.712	-0.191	4.73	-173.6
400.0	-0.820	-0.047	-1.71	-176.7
405.0	-0.510	-0.041	-5.83	-175.4
410.0	-0.309	-0.041	-10.13	-172.4
415.0	0.083	-0.088	-18.34	-46.8
420.0	-2.102	-0.272	6.53	-172.6
425.0	-0.910	-0.013	-0.82	-179.2
430.0	-0.837	0.007	-1.54	179.5
435.0	-0.944	0.026	-0.49	178.4
440.0	-1.330	0.068	2.49	177.1
445.0	-3.210	0.856	10.43	165.1
450.0	3.031	0.762	9.90	14.1
455.0	1.003	0.111	0.08	6.3
460.0	0.538	0.040	-5.36	4.3
465.0	0.261	0.037	-11.58	8.1
470.0	-0.062	0.078	-19.98	128.5
475.0	-1.941	0.749	6.37	158.9
480.0	1.471	0.126	3.38	4.9
485.0	0.976	0.010	-0.21	0.6
490.0	0.931	-0.007	-0.62	-0.4
495.0	1.113	-0.029	0.93	-1.5
500.0	1.796	-0.094	5.10	-3.0



Solid Line Depicts Black Material and Dashed Line Depicts Red Material

Figure 2. Transfer Function of 2-mm Samples

Table 3. Transfer Function of 4-mm-Thick Standard Silicone Rubber

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
0.0	0.621	0.000	-4.14	0.0
5.0	1.145	0.037	1.18	1.9
10.0	0.749	0.052	-2.49	4.0
15.0	-0.289	-0.050	-10.66	-170.1
20.0	-0.047	0.028	-25.19	149.3
25.0	-0.093	0.077	-18.32	140.3
30.0	0.139	-0.020	-17.02	-8.3
35.0	0.534	-0.021	-5.45	-2.3
40.0	1.880	-0.231	5.55	-7.0
45.0	-4.280	-0.584	12.71	-172.2
50.0	-1.410	-0.026	2.99	-179.0
55.0	-1.055	-0.007	0.46	-179.6
60.0	-1.005	0.003	0.04	179.8
65.0	-1.223	0.026	1.75	178.8
70.0	-2.826	0.280	9.07	174.3
75.0	1.290	0.168	2.29	7.4
80.0	0.200	0.033	-13.87	9.3
85.0	-0.137	0.019	-17.18	172.2
90.0	-0.426	0.035	-7.39	175.3
95.0	-1.079	0.012	0.66	179.3
100.0	-7.412	3.620	18.33	154.0
105.0	2.250	0.285	7.11	7.2
110.0	1.207	0.022	1.63	1.1
115.0	0.976	0.009	-0.21	0.5
120.0	0.980	-0.005	-0.18	-0.3
125.0	1.334	-0.049	2.51	-2.1
130.0	-0.278	-5.112	14.18	-93.1
135.0	-0.298	-0.098	-10.08	-161.7
140.0	0.132	-0.022	-17.47	-9.3
145.0	0.393	-0.024	-8.11	-3.4
150.0	0.796	-0.051	-1.97	-3.7
155.0	1.965	-0.186	5.91	-5.4
160.0	-5.950	-2.294	16.09	-158.9
165.0	-1.605	-0.095	4.13	-176.6
170.0	-1.040	-0.019	0.34	-179.0
175.0	-0.891	-0.005	-1.00	-179.7
180.0	-0.937	0.008	-0.57	179.5
185.0	-1.596	0.159	4.11	174.3
190.0	0.670	0.166	-3.22	13.9
195.0	-0.162	0.036	-15.61	167.6
200.0	-0.398	0.026	-7.99	176.3
205.0	-0.651	0.038	-3.71	176.7
210.0	-1.238	0.074	1.87	176.6
215.0	-4.987	2.151	14.70	156.7
220.0	2.532	0.221	8.10	5.0
225.0	1.236	0.044	1.84	2.1
230.0	0.882	0.014	-1.09	0.9
235.0	0.775	0.006	-2.21	0.4
240.0	0.837	-0.011	-1.54	-0.8
245.0	1.884	-0.954	6.49	-26.8
250.0	0.187	-0.044	-14.35	-13.2

Table 3. Transfer Function of 4-mm-Thick Standard Silicone Rubber (Cont'd)

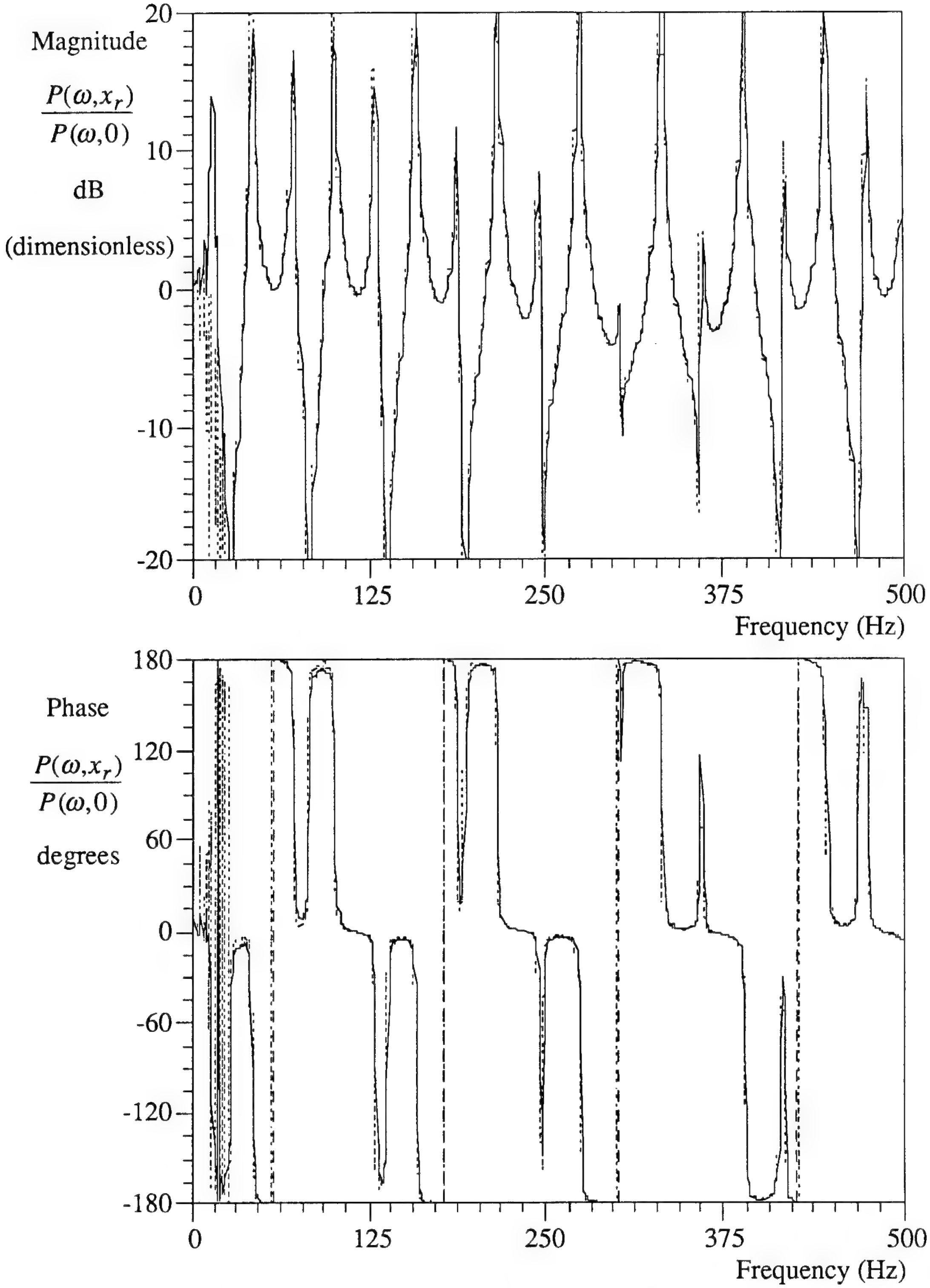
Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
255.0	0.434	-0.017	-7.24	-2.3
260.0	0.618	-0.021	-4.17	-2.0
265.0	0.958	-0.057	-0.36	-3.4
270.0	2.094	-0.227	6.47	-6.2
275.0	-7.039	-4.977	18.71	-144.7
280.0	-1.631	-0.154	4.29	-174.6
285.0	-0.966	-0.039	-0.30	-177.7
290.0	-0.721	-0.018	-2.84	-178.6
295.0	-0.625	-0.009	-4.09	-179.1
300.0	-0.636	-0.001	-3.93	-180.0
305.0	-0.370	0.064	-8.50	170.2
310.0	-0.513	0.017	-5.79	178.1
315.0	-0.626	0.016	-4.07	178.5
320.0	-0.806	0.030	-1.86	177.9
325.0	-1.319	0.073	2.42	176.8
330.0	-4.196	0.863	12.64	168.4
335.0	3.207	0.564	10.25	10.0
340.0	1.184	0.059	1.48	2.9
345.0	0.733	0.031	-2.70	2.5
350.0	0.527	0.018	-5.56	1.9
355.0	0.362	0.032	-8.79	5.0
360.0	-0.149	0.602	-4.15	103.9
365.0	0.782	0.002	-2.14	0.1
370.0	0.708	-0.006	-3.00	-0.5
375.0	0.795	-0.019	-1.99	-1.4
380.0	1.061	-0.053	0.53	-2.9
385.0	1.848	-0.251	5.42	-7.7
390.0	-1.348	-11.558	21.32	-96.7
395.0	-1.756	-0.197	4.94	-173.6
400.0	-0.830	-0.057	-1.60	-176.0
405.0	-0.520	-0.033	-5.66	-176.4
410.0	-0.310	-0.044	-10.08	-172.0
415.0	0.092	-0.117	-16.56	-51.7
420.0	-1.971	-0.664	6.36	-161.4
425.0	-0.911	-0.016	-0.81	-179.0
430.0	-0.836	0.004	-1.56	179.7
435.0	-0.956	0.029	-0.38	178.3
440.0	-1.384	0.088	2.84	176.3
445.0	-3.461	0.664	10.94	169.1
450.0	2.881	0.924	9.62	17.8
455.0	1.030	0.104	0.30	5.8
460.0	0.528	0.031	-5.53	3.3
465.0	0.252	0.034	-11.90	7.6
470.0	-0.056	0.049	-22.57	139.0
475.0	-1.562	0.767	4.81	153.9
480.0	1.510	0.145	3.62	5.5
485.0	0.979	0.016	-0.18	0.9
490.0	0.930	-0.005	-0.63	-0.3
495.0	1.103	-0.028	0.85	-1.5
500.0	1.748	-0.168	4.89	-5.5

Table 4. Transfer Function of 4-mm-Thick Silicone Rubber With Embedded Iron Powder and Glass Microbeads

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
0.0	0.677	0.000	-3.38	0.0
5.0	1.114	-0.013	0.94	-0.7
10.0	1.368	0.195	2.81	8.1
15.0	-1.936	-4.605	13.97	-112.8
20.0	-0.497	-0.025	-6.07	-177.2
25.0	-0.166	-0.053	-15.19	-162.4
30.0	0.130	-0.049	-17.13	-20.4
35.0	0.507	-0.080	-5.79	-8.9
40.0	1.768	-0.344	5.11	-11.0
45.0	-4.356	-0.918	12.97	-168.1
50.0	-1.444	-0.059	3.20	-177.6
55.0	-1.055	-0.008	0.47	-179.6
60.0	-1.005	0.004	0.04	179.8
65.0	-1.212	0.034	1.67	178.4
70.0	-2.713	0.434	8.78	170.9
75.0	1.334	0.352	2.79	14.8
80.0	0.231	0.065	-12.39	15.8
85.0	-0.118	0.037	-18.16	162.6
90.0	-0.399	0.047	-7.92	173.2
95.0	-1.011	0.133	0.16	172.5
100.0	-4.653	2.751	14.66	149.4
105.0	2.401	0.333	7.69	7.9
110.0	1.234	0.047	1.83	2.2
115.0	0.983	0.012	-0.15	0.7
120.0	0.984	-0.003	-0.14	-0.2
125.0	1.330	-0.090	2.50	-3.8
130.0	0.232	-5.329	14.54	-87.5
135.0	-0.330	-0.087	-9.34	-165.3
140.0	0.114	-0.041	-18.34	-20.0
145.0	0.372	-0.034	-8.56	-5.3
150.0	0.751	-0.056	-2.47	-4.3
155.0	1.867	-0.254	5.50	-7.7
160.0	-6.129	-2.592	16.46	-157.1
165.0	-1.667	-0.052	4.44	-178.2
170.0	-1.051	-0.030	0.43	-178.4
175.0	-0.895	-0.008	-0.97	-179.5
180.0	-0.940	0.005	-0.54	179.7
185.0	-1.554	0.114	3.85	175.8
190.0	0.651	0.228	-3.22	19.3
195.0	-0.141	0.056	-16.38	158.4
200.0	-0.386	0.035	-8.24	174.8
205.0	-0.631	0.039	-3.98	176.4
210.0	-1.214	0.088	1.71	175.9
215.0	-5.021	1.448	14.36	163.9
220.0	2.675	0.290	8.60	6.2
225.0	1.234	0.057	1.83	2.6
230.0	0.891	0.021	-1.00	1.4
235.0	0.783	0.007	-2.12	0.5
240.0	0.856	-0.007	-1.35	-0.5

Table 4. Transfer Function of 4-mm-Thick Silicone Rubber With Embedded Iron Powder and Glass Microbeads (Cont'd)

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
245.0	1.816	-0.871	6.08	-25.6
250.0	0.161	-0.053	-15.39	-18.2
255.0	0.419	-0.031	-7.54	-4.3
260.0	0.609	-0.033	-4.29	-3.1
265.0	0.931	-0.053	-0.60	-3.2
270.0	1.948	-0.240	5.86	-7.0
275.0	-7.518	-7.163	20.33	-136.4
280.0	-1.711	-0.144	4.70	-175.2
285.0	-0.958	-0.048	-0.36	-177.1
290.0	-0.727	-0.020	-2.76	-178.4
295.0	-0.633	-0.012	-3.97	-178.9
300.0	-0.647	-0.007	-3.78	-179.4
305.0	-0.341	0.103	-8.96	163.3
310.0	-0.505	0.019	-5.92	177.8
315.0	-0.617	0.016	-4.19	178.5
320.0	-0.806	0.032	-1.86	177.7
325.0	-1.291	0.069	2.23	176.9
330.0	-4.108	0.935	12.49	167.2
335.0	3.187	0.708	10.28	12.5
340.0	1.181	0.104	1.48	5.0
345.0	0.751	0.031	-2.48	2.3
350.0	0.542	0.020	-5.31	2.1
355.0	0.382	0.031	-8.33	4.7
360.0	-0.239	0.474	-5.51	116.7
365.0	0.770	0.013	-2.27	0.9
370.0	0.702	-0.006	-3.07	-0.5
375.0	0.791	-0.020	-2.04	-1.4
380.0	1.036	-0.050	0.31	-2.8
385.0	1.863	-0.214	5.46	-6.5
390.0	2.904	-12.034	21.85	-76.4
395.0	-1.722	-0.141	4.75	-175.3
400.0	-0.842	-0.051	-1.47	-176.5
405.0	-0.512	-0.042	-5.79	-175.3
410.0	-0.315	-0.038	-9.96	-173.1
415.0	0.030	-0.100	-19.60	-73.2
420.0	-2.027	-0.642	6.55	-162.4
425.0	-0.910	-0.015	-0.82	-179.0
430.0	-0.832	0.005	-1.60	179.6
435.0	-0.951	0.025	-0.43	178.5
440.0	-1.346	0.092	2.60	176.1
445.0	-3.527	0.731	11.13	168.3
450.0	3.304	0.711	10.58	12.1
455.0	1.027	0.103	0.28	5.7
460.0	0.551	0.046	-5.15	4.8
465.0	0.274	0.031	-11.18	6.5
470.0	-0.043	0.055	-23.12	128.5
475.0	-1.713	1.054	6.07	148.4
480.0	1.451	0.124	3.26	4.9
485.0	0.970	0.021	-0.26	1.2
490.0	0.931	-0.008	-0.62	-0.5
495.0	1.099	-0.028	0.82	-1.4
500.0	1.768	-0.145	4.98	-4.7



Solid Line Depicts Black Material and Dashed Line Depicts Red Material

Figure 3. Transfer Function of 4-mm Samples

Table 5. Transfer Function of 6-mm-Thick Standard Silicone Rubber

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
0.0	0.794	0.000	-2.00	0.0
5.0	1.036	-0.048	0.32	-2.7
10.0	1.008	0.139	0.15	7.8
15.0	1.209	-0.062	1.66	-2.9
20.0	-0.333	-1.001	0.47	-108.4
25.0	-0.441	-0.319	-5.28	-144.1
30.0	-0.161	-0.204	-11.70	-128.2
35.0	0.121	-0.211	-12.28	-60.2
40.0	0.584	-0.418	-2.87	-35.6
45.0	1.093	-3.910	12.17	-74.4
50.0	-1.687	-0.297	4.67	-170.0
55.0	-1.119	-0.050	0.98	-177.5
60.0	-1.011	0.001	0.09	180.0
65.0	-1.141	0.045	1.15	177.7
70.0	-1.921	0.328	5.79	170.3
75.0	2.274	2.181	9.97	43.8
80.0	0.466	0.177	-6.06	20.8
85.0	0.034	0.084	-20.83	68.1
90.0	-0.256	0.087	-11.37	161.3
95.0	-0.743	0.172	-2.35	167.0
100.0	-2.365	1.129	8.37	154.5
105.0	3.038	0.914	10.03	16.7
110.0	1.335	0.075	2.52	3.2
115.0	1.019	0.020	0.16	1.1
120.0	0.993	0.001	-0.06	0.1
125.0	1.280	-0.059	2.15	-2.6
130.0	3.238	-1.801	11.38	-29.1
135.0	-0.609	-0.254	-3.61	-157.4
140.0	-0.001	-0.083	-21.60	-90.8
145.0	0.286	-0.058	-10.70	-11.4
150.0	0.628	-0.066	-3.99	-6.0
155.0	1.744	-0.331	4.98	-10.8
160.0	-3.072	-4.496	14.72	-124.3
165.0	-1.781	-0.173	5.05	-174.4
170.0	-1.100	-0.042	0.83	-177.8
175.0	-0.925	-0.013	-0.68	-179.2
180.0	-0.953	0.008	-0.42	179.5
185.0	-1.459	0.085	3.29	176.7
190.0	1.251	0.857	3.61	34.4
195.0	-0.014	0.075	-22.36	100.8
200.0	-0.313	0.032	-10.05	174.2
205.0	-0.567	0.037	-4.91	176.3
210.0	-1.089	0.099	0.78	174.8
215.0	-3.750	0.962	11.76	165.6
220.0	3.068	0.468	9.84	8.7
225.0	1.319	0.070	2.42	3.0
230.0	0.927	0.023	-0.66	1.4
235.0	0.815	0.012	-1.77	0.9
240.0	0.882	-0.013	-1.09	-0.8
245.0	2.078	-0.668	6.78	-17.8
250.0	0.024	-0.085	-21.03	-74.1
255.0	0.354	-0.033	-8.97	-5.3

Table 5. Transfer Function of 6-mm-Thick Standard Silicone Rubber (Cont'd)

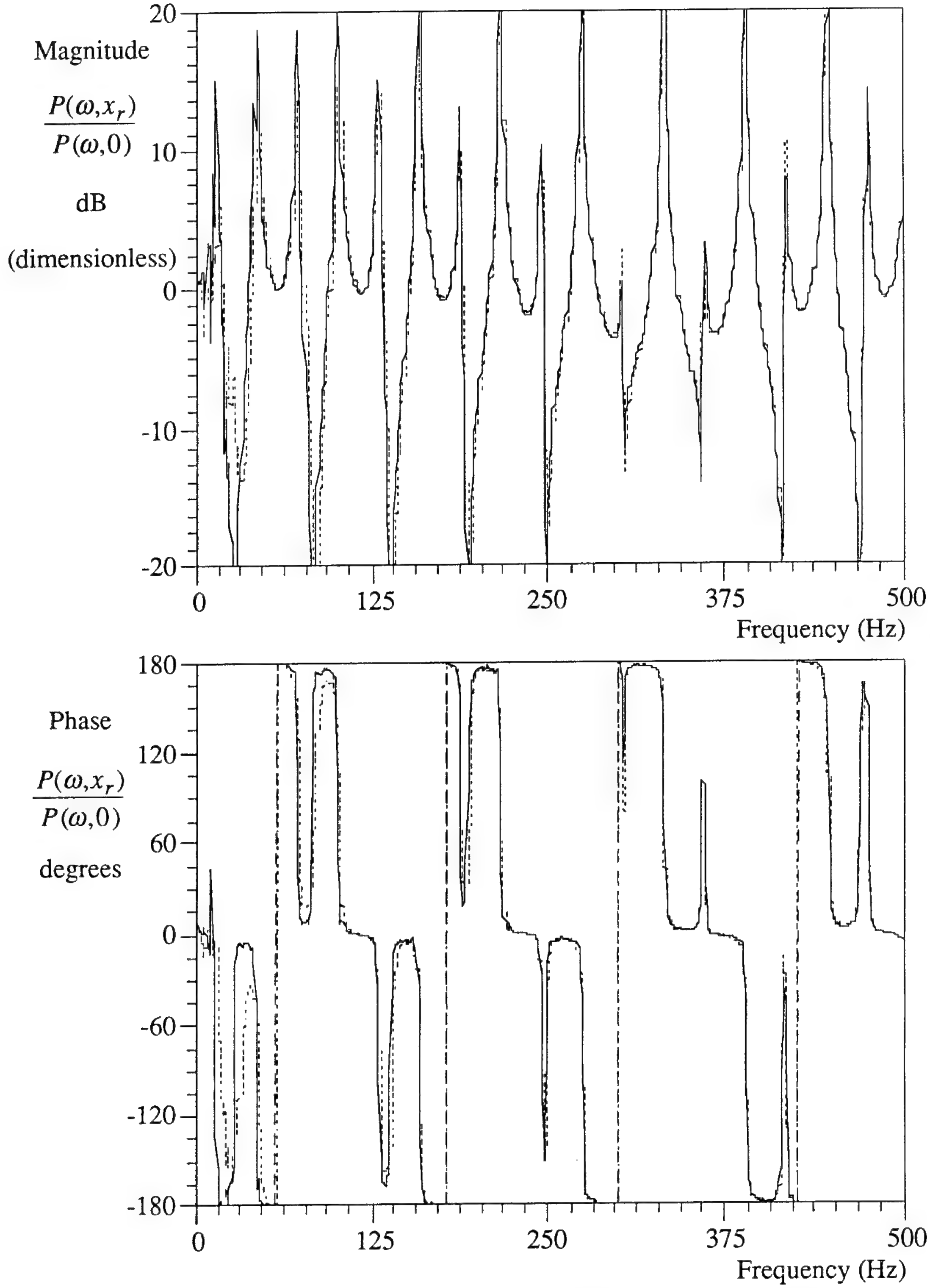
Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
260.0	0.549	-0.027	-5.19	-2.9
265.0	0.883	-0.044	-1.07	-2.8
270.0	1.789	-0.155	5.08	-5.0
275.0	-2.265	-11.355	21.27	-101.3
280.0	-1.821	-0.161	5.24	-174.9
285.0	-1.037	-0.049	0.32	-177.3
290.0	-0.769	-0.024	-2.27	-178.2
295.0	-0.676	-0.013	-3.40	-178.9
300.0	-0.729	0.011	-2.74	179.1
305.0	-0.094	0.194	-13.35	115.9
310.0	-0.454	0.022	-6.86	177.3
315.0	-0.577	0.021	-4.78	177.9
320.0	-0.773	0.029	-2.24	177.9
325.0	-1.224	0.099	1.79	175.4
330.0	-3.242	0.617	10.37	169.2
335.0	3.611	0.817	11.37	12.7
340.0	1.283	0.085	2.18	3.8
345.0	0.782	0.031	-2.13	2.2
350.0	0.580	0.020	-4.72	2.0
355.0	0.438	0.039	-7.14	5.1
360.0	0.127	0.280	-10.25	65.6
365.0	0.699	0.001	-3.11	0.1
370.0	0.663	-0.010	-3.56	-0.9
375.0	0.756	-0.019	-2.42	-1.4
380.0	1.008	-0.051	0.08	-2.9
385.0	1.828	-0.176	5.28	-5.5
390.0	5.409	-9.023	20.44	-59.1
395.0	-1.857	-0.215	5.43	-173.4
400.0	-0.895	-0.061	-0.94	-176.1
405.0	-0.567	-0.031	-4.91	-176.9
410.0	-0.371	-0.019	-8.61	-177.0
415.0	-0.078	-0.039	-21.18	-153.6
420.0	-2.222	-0.579	7.22	-165.4
425.0	-0.881	-0.009	-1.10	-179.4
430.0	-0.805	0.009	-1.88	179.3
435.0	-0.919	0.030	-0.73	178.1
440.0	-1.283	0.093	2.19	175.8
445.0	-2.723	0.666	8.95	166.3
450.0	3.954	1.772	12.74	24.1
455.0	1.118	0.119	1.02	6.1
460.0	0.594	0.050	-4.50	4.8
465.0	0.329	0.039	-9.60	6.8
470.0	0.044	0.061	-22.52	54.0
475.0	-1.054	0.491	1.31	155.0
480.0	1.504	0.145	3.59	5.5
485.0	0.948	0.017	-0.46	1.0
490.0	0.910	-0.005	-0.82	-0.3
495.0	1.072	-0.035	0.60	-1.8
500.0	1.692	-0.110	4.58	-3.7

Table 6. Transfer Function of 6-mm-Thick Silicone Rubber With Embedded Iron Powder and Glass Microbeads

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
0.0	0.725	0.000	-2.79	0.0
5.0	1.121	0.025	0.99	1.3
10.0	1.408	-0.313	3.18	-12.5
15.0	-3.903	-4.176	15.14	-133.1
20.0	-0.578	0.008	-4.76	179.2
25.0	-0.142	-0.030	-16.79	-168.2
30.0	0.138	-0.031	-16.95	-12.8
35.0	0.519	-0.036	-5.68	-4.0
40.0	1.822	-0.302	5.33	-9.4
45.0	-4.399	-0.850	13.03	-169.1
50.0	-1.422	-0.038	3.06	-178.5
55.0	-1.057	-0.008	0.48	-179.6
60.0	-1.006	0.003	0.05	179.8
65.0	-1.226	0.031	1.77	178.5
70.0	-2.974	0.379	9.54	172.7
75.0	1.397	0.257	3.05	10.4
80.0	0.208	0.041	-13.46	11.1
85.0	-0.117	0.032	-18.30	164.9
90.0	-0.427	0.044	-7.35	174.1
95.0	-1.030	0.074	0.28	175.9
100.0	-5.908	3.036	16.45	152.8
105.0	2.221	0.293	7.00	7.5
110.0	1.228	0.021	1.78	1.0
115.0	0.980	0.009	-0.17	0.5
120.0	0.987	-0.001	-0.12	-0.1
125.0	1.346	-0.041	2.59	-1.8
130.0	-0.618	-5.675	15.13	-96.2
135.0	-0.347	-0.076	-9.00	-167.7
140.0	0.128	-0.030	-17.60	-13.3
145.0	0.375	-0.028	-8.50	-4.2
150.0	0.760	-0.049	-2.37	-3.7
155.0	1.864	-0.159	5.44	-4.9
160.0	-5.916	-1.425	15.68	-166.5
165.0	-1.627	-0.075	4.24	-177.4
170.0	-1.063	-0.026	0.53	-178.6
175.0	-0.896	-0.007	-0.95	-179.6
180.0	-0.948	0.012	-0.46	179.3
185.0	-1.588	0.217	4.10	172.2
190.0	0.585	0.186	-4.24	17.6
195.0	-0.140	0.028	-16.92	168.8
200.0	-0.380	0.031	-8.39	175.3
205.0	-0.632	0.029	-3.98	177.4
210.0	-1.224	0.101	1.78	175.3
215.0	-5.617	1.537	15.30	164.7
220.0	2.701	0.183	8.65	3.9
225.0	1.224	0.061	1.77	2.9
230.0	0.890	0.021	-1.01	1.3
235.0	0.790	0.006	-2.05	0.5
240.0	0.876	-0.008	-1.15	-0.5
245.0	2.915	-1.426	10.22	-26.1
250.0	0.147	-0.051	-16.17	-19.3

Table 6. Transfer Function of 6-mm-Thick Silicone Rubber With Embedded Iron Powder and Glass Microbeads (Cont'd)

Frequency (Hertz)	Real (T) (dimensionless)	Imag (T) (dimensionless)	Magnitude (dB)	Phase (degrees)
255.0	0.404	-0.032	-7.83	-4.6
260.0	0.601	-0.024	-4.42	-2.2
265.0	0.954	-0.072	-0.39	-4.3
270.0	2.006	-0.177	6.08	-5.0
275.0	-6.893	-5.668	19.01	-140.6
280.0	-1.703	-0.126	4.65	-175.8
285.0	-0.969	-0.037	-0.27	-177.8
290.0	-0.741	-0.019	-2.60	-178.6
295.0	-0.648	-0.012	-3.76	-179.0
300.0	-0.692	0.002	-3.20	179.9
305.0	-0.257	0.113	-11.03	156.3
310.0	-0.487	0.020	-6.25	177.7
315.0	-0.604	0.023	-4.38	177.8
320.0	-0.796	0.035	-1.97	177.5
325.0	-1.303	0.088	2.32	176.1
330.0	-3.758	0.863	11.72	167.1
335.0	3.498	0.503	10.97	8.2
340.0	1.183	0.056	1.47	2.7
345.0	0.758	0.033	-2.39	2.5
350.0	0.553	0.020	-5.13	2.0
355.0	0.417	0.031	-7.58	4.2
360.0	-0.078	0.421	-7.36	100.4
365.0	0.739	0.002	-2.63	0.2
370.0	0.684	-0.011	-3.29	-0.9
375.0	0.775	-0.016	-2.21	-1.2
380.0	1.044	-0.039	0.38	-2.1
385.0	1.917	-0.147	5.68	-4.4
390.0	-0.353	-11.986	21.58	-91.7
395.0	-1.722	-0.202	4.78	-173.3
400.0	-0.854	-0.050	-1.35	-176.6
405.0	-0.540	-0.033	-5.33	-176.5
410.0	-0.344	-0.028	-9.24	-175.4
415.0	-0.005	-0.087	-21.18	-93.5
420.0	-1.951	-0.542	6.13	-164.5
425.0	-0.873	-0.013	-1.18	-179.1
430.0	-0.811	0.006	-1.82	179.6
435.0	-0.927	0.021	-0.65	178.7
440.0	-1.323	0.074	2.44	176.8
445.0	-3.092	0.463	9.90	171.5
450.0	3.377	0.865	10.85	14.4
455.0	1.054	0.100	0.49	5.4
460.0	0.573	0.037	-4.82	3.7
465.0	0.304	0.036	-10.27	6.8
470.0	0.010	0.040	-27.74	75.7
475.0	-1.624	0.698	4.95	156.7
480.0	1.456	0.086	3.28	3.4
485.0	0.953	0.011	-0.42	0.7
490.0	0.917	-0.005	-0.75	-0.3
495.0	1.088	-0.027	0.74	-1.4
500.0	1.791	-0.137	5.09	-4.4



Solid Line Depicts Black Material and Dashed Line Depicts Red Material

Figure 4. Transfer Function of 6-mm Samples

Table 7. Real and Imaginary Parts of Eigenvalues
Extracted From the Transfer Functions

Eigenvalue	Real Part (Hz)	Imaginary Part (Hz)
1	-0.294	14.6
2	-0.285	43.4
3	-0.448	72.0
4	-0.587	100.9
5	-0.541	129.9
6	-0.537	158.9
7	-0.437	187.7
8	-0.460	216.5
9	-0.380	245.4
10	-0.576	274.4
11	-0.730	302.6
12	-0.583	332.3
13	-0.647	361.2
14	-0.632	390.0
15	-0.570	419.0
16	-0.551	447.8
17	-0.531	476.5

DYNAMIC STRUCTURAL TESTING OF MOLD-EX SILICONE MX-111 SAMPLES

In a series of related tests (not covered under the CRADA, but believed to be of interest to Loctite), dynamic structural evaluations were completed by NUWC Detachment New London in order to study structureborne acoustics and attenuation characteristics.

A batch of NBS Silicone MX-111 material was requested from the Mold-Ex Rubber Company, Inc., in Milton, Florida, and from G. Thomas, the co-inventor of this quieting material, who is affiliated with the Naval Medical Research & Development Center (NMRDC) in Pensacola, Florida. From discussions with Mr. Thomas in the early spring of 1994, it was learned that the material in question was designated as a GM-41 polyurethane and that several industrial companies, such as Boeing and General Motors, were conducting airborne tests for aerospace and automobile applications.

Two 1-foot-square pieces of the Mold-Ex silicone MX-111 samples, with thicknesses of 3 and 6 mm thick, respectively, were provided for the dynamic structural testing. A series of experiments were conducted on the Metravib Viscoanalyzer to determine the complex Young's modulus and the amount of intrinsic structural damping as a function of frequency ($5 < f < 500$ Hz) and temperature (-40° C < T < 40° C). The viscoanalyzer provides information on the structural and damping characteristics of polymers when they are subjected to forced harmonic oscillations off resonance. It produces measurements of the displacement and force and provides a complex dynamic stiffness and a loss angle measure of the material. Based on the theory of viscoelasticity, the Young's and shearing modulus (both real and imaginary) are calculated from the geometry of the specimen.

For structural testing, the sample specimen was 5.7 mm high, 5.3 mm thick, and 4.7 mm wide. The various stiffness and phase angle values as measured by the viscoanalyzer are documented in appendix A for each indicated temperature and frequency. The tests were performed in the tension-compression mode, with a displacement vector of 5 microns for each test. Hence, only a measure of the Young's modulus was acquired. Figure 5 is a plot of stiffness versus frequency and phase angle versus frequency for 10 different temperatures. The stiffness decreases for all frequency values as the temperature increases, which is consistent with other observations. The phase angle hovers around 20 degrees for virtually all temperatures and frequencies. It appears that the stiffness and corresponding phase values at 10° C and higher (pages A-9 to A-12) for frequencies approaching 500 Hz may not be as reliable. From the data, it appears that resonance was occurring for those states. The results in general (in the absence of resonance) are accurate within plus or minus 5 percent. Calibration on the viscoanalyzer for the required frequency sweeps is usually achieved with a metallic aluminum ring.

Figure 6 illustrates the real elastic moduli (E) and tangent delta versus temperature for the MX-111 material. The results are very similar to those in figure 5 for stiffness. The data sheets in appendix B show the real and imaginary values of the elastic moduli as well as the tangent delta (measure of lossiness) for each operating temperature. All the values were calculated with the computer software developed by Metravib. The tests were run isothermally at 10 distinct temperatures for each frequency sweep of interest.

Figure 7 shows the real elastic moduli and the tangent delta versus frequency. Overall the MX-111 material shows very consistent damping from 5 to 450 Hz at levels of 0.35 to 0.40. Based on the previous discussion concerning resonance, the data points in this figure near 450 to 500 Hz

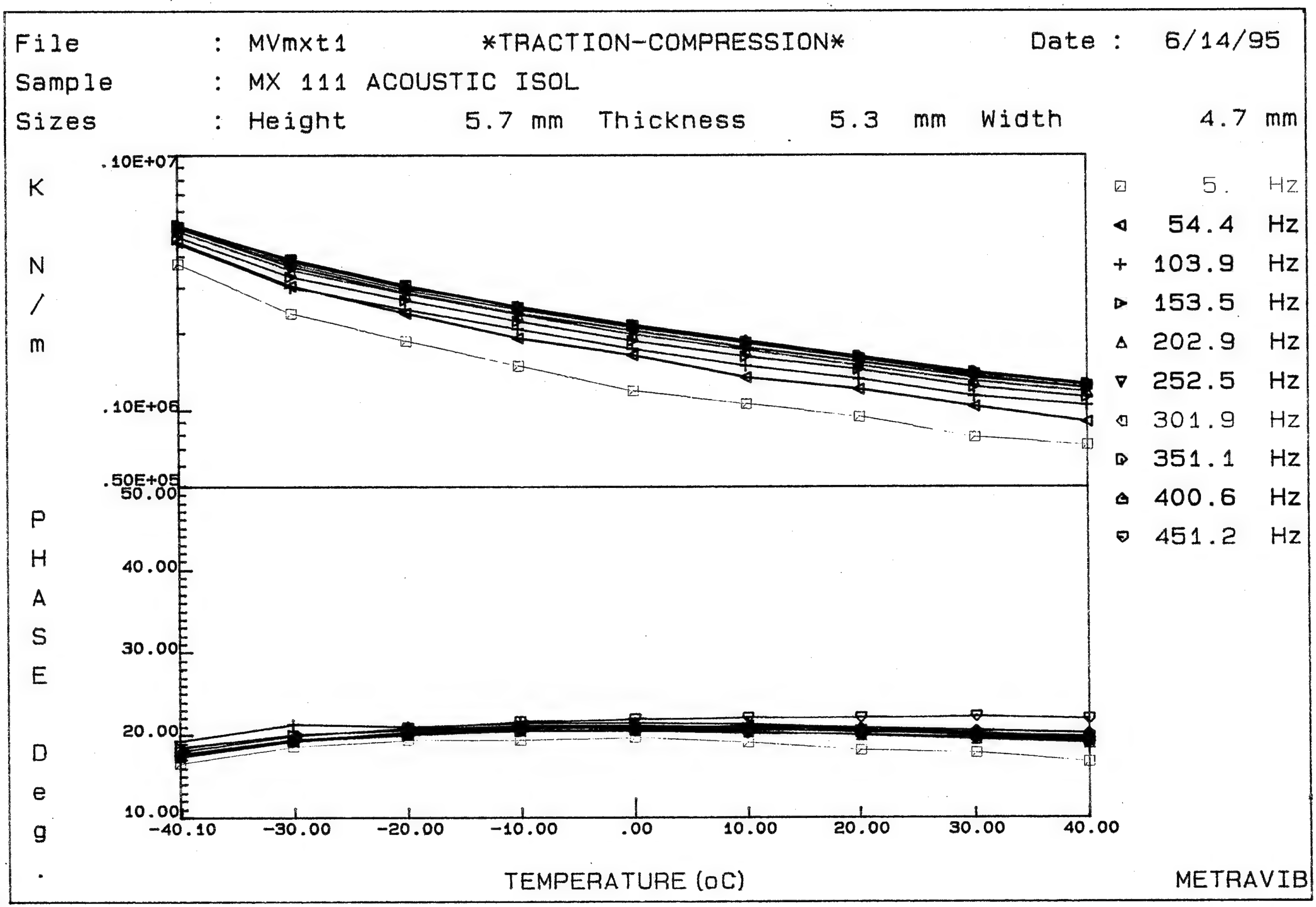


Figure 5. Plot of Stiffness Versus Frequency and Phase Angle Versus Frequency at 10 Temperatures

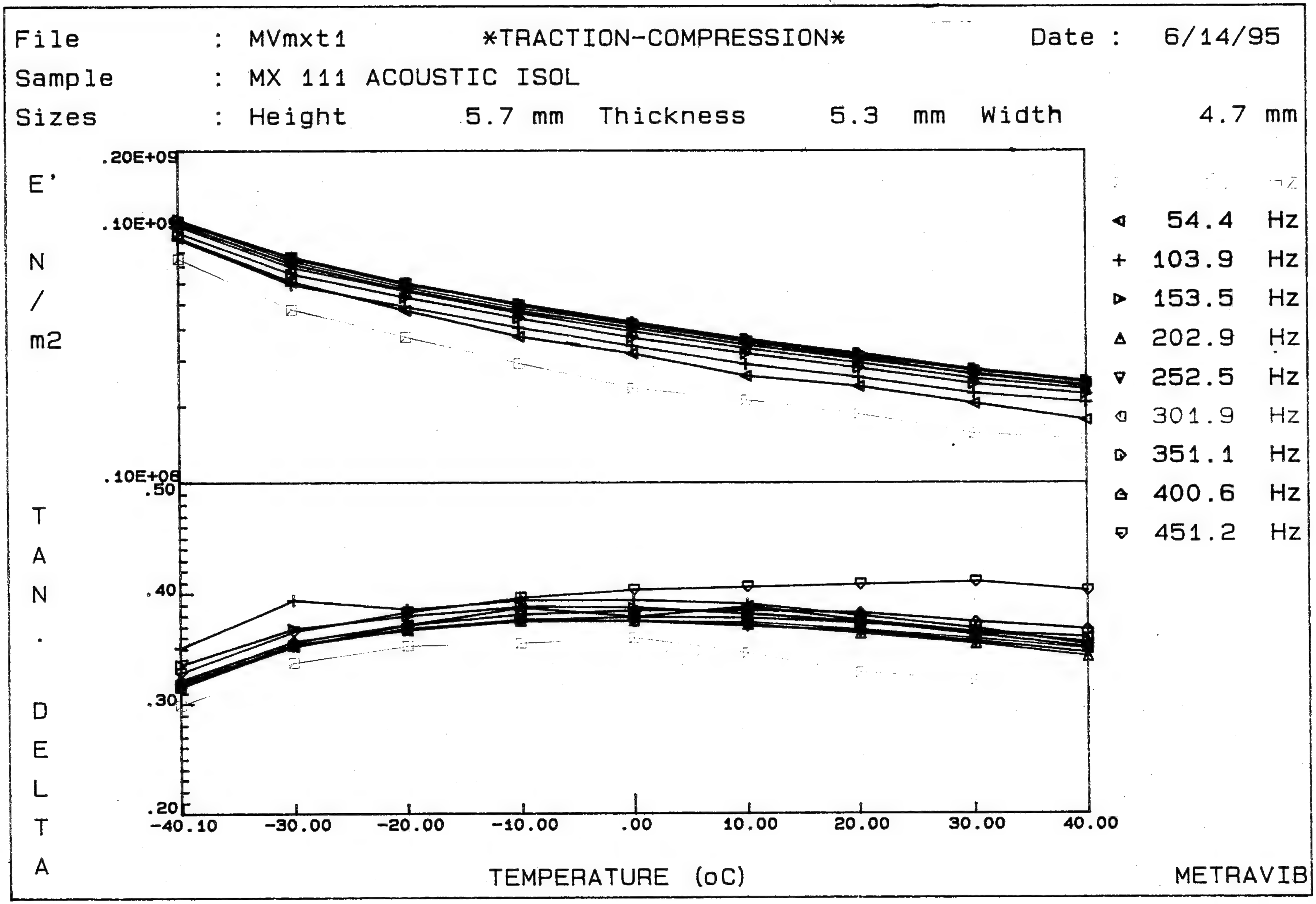


Figure 6. Plot of the Real Elastic Moduli and Tangent Delta Versus Temperature

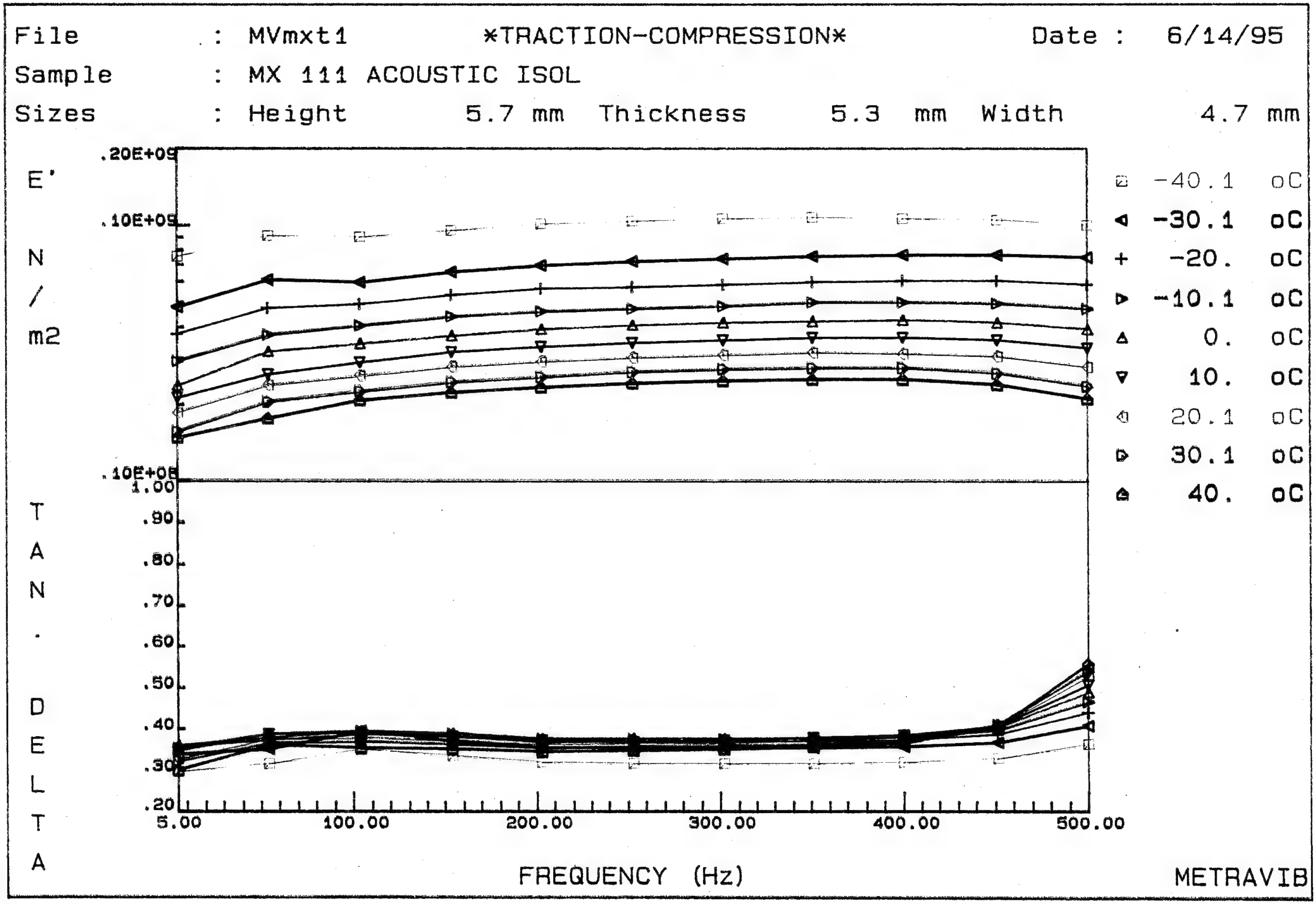


Figure 7. Plot of the Real Elastic Moduli and Tangent Delta Versus Frequency

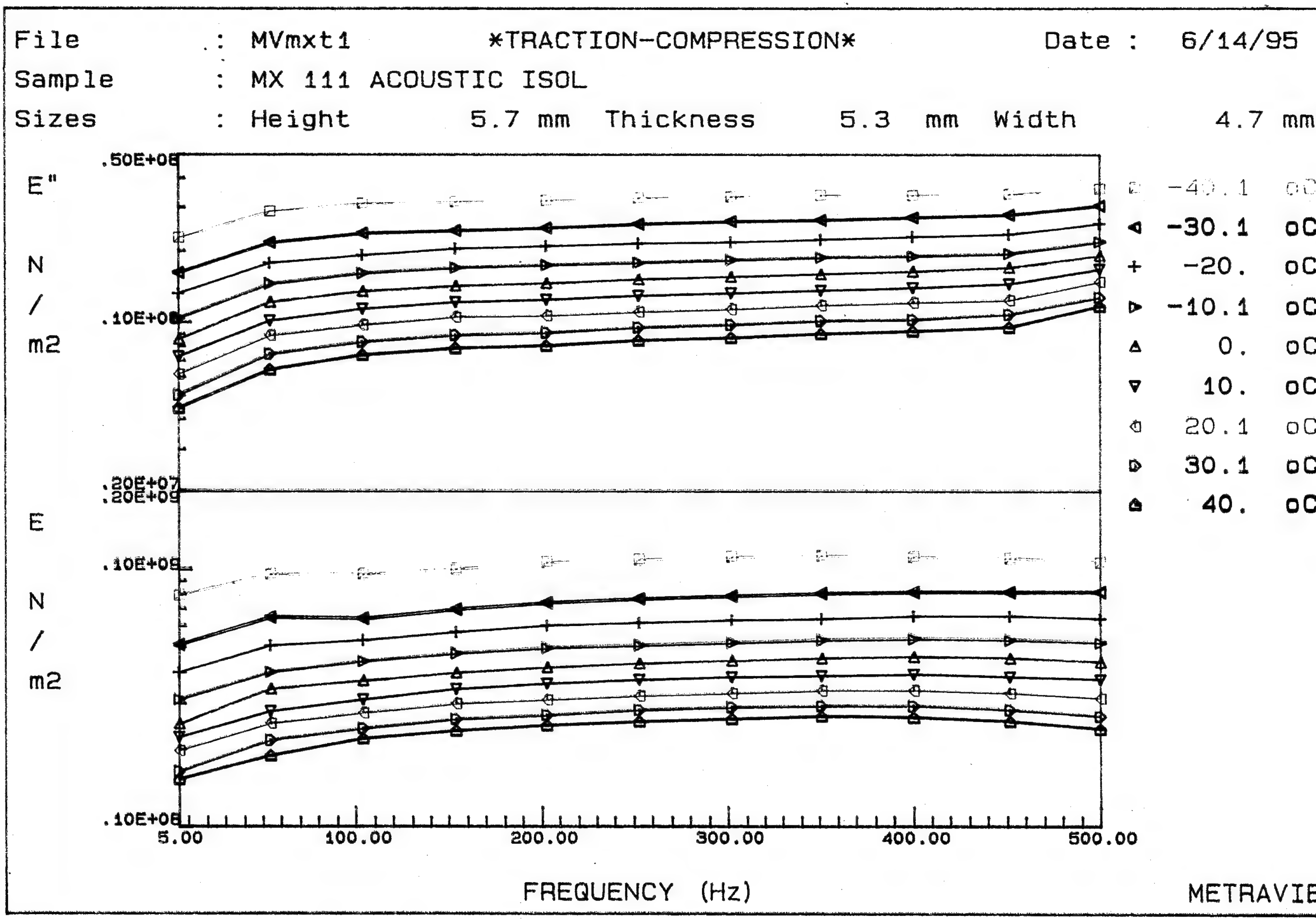


Figure 8. Plot of the Imaginary Elastic Moduli and Total Elastic Moduli Versus Frequency at 10 Temperatures

would not be considered totally accurate. The sudden increase in the damping (tangent delta = E''/E') in that region is not a true reflection of the material—it is the onset of resonance.

Figure 8 is a plot of the imaginary elastic moduli and the total elastic moduli versus frequency at the 10 temperature states. The data show that the structure is stiffest at low temperatures at all frequencies and that the imaginary component of the elastic moduli slightly increases with frequency for all temperatures. Again, these are fairly consistent results based on numerous other measurements. The attenuation values of the material are not especially high for all frequencies and temperatures. However, the damping values appear almost constant for the temperatures and frequencies measured. This is somewhat unusual and not very often seen in polymer testing. Also, the structural strength in tension and compression appears to be reasonable for the MX-111 material.

APPENDIX A—VARIOUS STIFFNESS AND PHASE ANGLE VALUES AS MEASURED BY THE METRAVIB VISCOANALYZER

VISCOANALYSEUR TO :

METRAVIB
instruments

MEASUREMENT FILE...................... MVmxt1

DATE.................................. 6/ 14/ 95

SAMPLE REFERENCE...................... MX 111 ACOUSTIC ISOL

TEST PERFORMED IN : TRACTION COMPRESSION

SAMPLE FEATURES :

- SHAPE.............................		PARALLELEPIPEDIC
- HEIGHT............................	5.79	mm
- THICKNESS.........................	5.35	mm
- WIDTH.............................	4.72	mm

MEASUREMENT CONDITIONS :

- SCANNING IN TEMPERATURE.............	-40.1 -	40.0	oC
- SCANNING IN FREQUENCY...............	5.0 -	500.0	HERTZ
- REGULATION IN DISPLACEMENT..........		5.0	MICRON
- PRESTRAIN REGULATION................			NO

REMARKS :

TEST PERFORMED BY :

SERVICE :

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 1

- STARTING TEMPERATURE................. 24.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -40.1 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	-158.6	1.8	4.9	.374E+06	16.5
2	54.5	-157.8	2.3	5.1	.453E+06	17.5
3	104.0	-154.1	2.3	5.2	.450E+06	19.2
4	153.6	-152.9	2.4	5.1	.474E+06	18.4
5	202.9	-152.5	2.5	5.0	.502E+06	17.6
6	252.5	-151.4	2.5	4.9	.515E+06	17.4
7	301.9	-151.7	2.6	5.0	.527E+06	17.4
8	351.1	-149.9	2.6	5.0	.533E+06	17.4
9	400.6	-145.2	2.6	5.0	.523E+06	17.6
10	451.3	-142.1	2.5	4.8	.520E+06	18.0
11	500.0	-140.8	2.5	5.0	.502E+06	19.7

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 2

- STARTING TEMPERATURE................ -40.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -30.1 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	-108.1	1.2	5.0	.239E+06	18.6
2	54.5	-108.2	1.6	5.2	.306E+06	19.3
3	104.0	-105.8	1.7	5.5	.303E+06	21.4
4	153.6	-105.8	1.7	5.1	.330E+06	20.1
5	202.9	-106.0	1.7	5.0	.351E+06	19.4
6	252.5	-106.3	1.8	5.0	.363E+06	19.3
7	301.9	-106.1	1.9	5.0	.372E+06	19.3
8	351.1	-106.0	1.9	5.0	.380E+06	19.3
9	400.6	-105.8	1.9	5.0	.385E+06	19.5
10	451.3	-105.5	1.9	5.0	.384E+06	19.9
11	500.0	-106.0	1.9	5.0	.382E+06	22.0

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 3

- STARTING TEMPERATURE................ -30.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -20.0 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	-79.7	.9	4.6	.187E+06	19.4
2	54.5	-80.2	1.2	5.0	.238E+06	20.3
3	104.0	-79.9	1.2	5.0	.248E+06	21.0
4	153.6	-79.9	1.3	4.9	.268E+06	20.7
5	202.9	-80.2	1.4	4.8	.283E+06	20.0
6	252.5	-80.5	1.4	5.0	.289E+06	20.1
7	301.9	-80.4	1.5	5.1	.296E+06	20.1
8	351.1	-80.0	1.5	5.0	.301E+06	20.1
9	400.6	-80.1	1.5	5.0	.306E+06	20.3
10	451.3	-79.9	1.5	5.0	.305E+06	20.9
11	500.0	-80.5	1.5	5.0	.301E+06	23.6

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 4

- STARTING TEMPERATURE................ -20.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -10.1 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	-55.4	.7	4.8	.149E+06	19.5
2	54.5	-55.9	1.0	5.3	.190E+06	21.1
3	104.0	-56.2	1.0	4.7	.208E+06	21.4
4	153.6	-56.2	1.1	4.8	.223E+06	21.1
5	202.9	-56.6	1.1	4.8	.235E+06	20.5
6	252.5	-56.8	1.2	5.0	.240E+06	20.5
7	301.9	-56.7	1.2	5.0	.246E+06	20.5
8	351.1	-57.0	1.3	5.0	.252E+06	20.5
9	400.6	-56.6	1.3	5.0	.253E+06	20.8
10	451.3	-56.5	1.3	5.0	.251E+06	21.5
11	500.0	-56.7	1.2	5.0	.246E+06	24.9

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 5

- STARTING TEMPERATURE................. -10.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE.................. .0 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	-33.4	.7	5.5	.120E+06	19.8
2	54.5	-34.0	.8	4.9	.163E+06	20.7
3	104.0	-34.2	.8	4.8	.175E+06	21.5
4	153.6	-34.6	.9	5.0	.187E+06	21.1
5	202.9	-35.3	1.0	5.0	.197E+06	20.5
6	252.5	-35.3	1.0	5.0	.205E+06	20.5
7	301.9	-35.3	1.0	5.0	.210E+06	20.5
8	351.1	-35.4	1.1	5.0	.214E+06	20.7
9	400.6	-35.3	1.1	5.0	.215E+06	20.9
10	451.3	-35.7	1.1	5.0	.213E+06	21.9
11	500.0	-35.7	1.0	5.0	.206E+06	25.9

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 6

- STARTING TEMPERATURE................ .0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 10.0 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	-13.5	.5	4.9	.106E+06	19.0
2	54.5	-13.7	.7	5.5	.134E+06	21.2
3	104.0	-14.1	.8	5.1	.148E+06	21.3
4	153.6	-14.7	.8	4.9	.162E+06	20.8
5	202.9	-15.4	.9	5.0	.171E+06	20.3
6	252.5	-15.3	.9	5.0	.176E+06	20.3
7	301.9	-15.7	.9	5.0	.181E+06	20.4
8	351.1	-15.6	.9	5.0	.184E+06	20.6
9	400.6	-15.6	.9	5.0	.186E+06	20.9
10	451.3	-15.7	.9	5.0	.182E+06	22.0
11	500.0	-16.5	.9	5.0	.176E+06	26.8

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 7

- STARTING TEMPERATURE.................. 10.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 20.1 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	5.2	.4	4.8	.939E+05	18.2
2	54.5	4.2	.6	4.8	.121E+06	20.5
3	104.0	4.2	.6	4.9	.132E+06	20.8
4	153.6	3.4	.7	4.9	.143E+06	20.5
5	202.9	3.4	.7	5.0	.149E+06	19.9
6	252.5	3.1	.8	5.0	.155E+06	20.1
7	301.9	3.2	.8	5.0	.158E+06	20.1
8	351.1	2.7	.8	5.0	.162E+06	20.4
9	400.6	3.0	.8	5.0	.162E+06	20.9
10	451.3	2.9	.8	5.0	.158E+06	22.1
11	500.0	2.7	.8	5.0	.151E+06	27.8

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 8

- STARTING TEMPERATURE................. 20.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 30.1 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	33.1	.4	5.6	.780E+05	17.8
2	54.5	32.7	.5	4.9	.103E+06	20.0
3	104.0	32.1	.6	5.1	.114E+06	20.2
4	153.6	31.6	.6	5.0	.124E+06	19.9
5	202.9	31.8	.7	5.0	.130E+06	19.4
6	252.5	31.4	.7	5.0	.135E+06	19.6
7	301.9	30.9	.7	5.0	.139E+06	19.7
8	351.1	30.8	.7	5.0	.141E+06	20.0
9	400.6	30.9	.7	5.0	.141E+06	20.5
10	451.3	31.0	.7	5.0	.136E+06	22.2
11	500.0	30.9	.6	5.0	.128E+06	28.4

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 9

- STARTING TEMPERATURE................ 30.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 40.0 oC

No	FREQUENCY HERTZ	PREDISTORTION MICRON	FORCE NEWTON	DISPLAC. MICRON	STIFFNESS NEWTON/METER	PHASE DEGREE
1	5.0	53.7	.4	5.1	.730E+05	16.7
2	54.5	52.9	.5	5.8	.895E+05	19.8
3	104.0	52.5	.5	4.9	.105E+06	19.4
4	153.6	51.9	.6	5.0	.112E+06	19.3
5	202.9	51.7	.6	5.0	.118E+06	18.9
6	252.5	51.3	.6	5.0	.122E+06	19.1
7	301.9	50.7	.6	5.0	.125E+06	19.2
8	351.1	50.7	.6	5.0	.127E+06	19.5
9	400.6	50.4	.6	5.0	.127E+06	20.1
10	451.3	50.3	.6	5.0	.122E+06	21.9
11	500.0	49.9	.6	5.0	.114E+06	29.1

APPENDIX B—REAL AND IMAGINARY VALUES OF THE ELASTIC MODULI AND THE TANGENT DELTA (MEASURE OF LOSSINESS) FOR EACH OPERATING TEMPERATURE

VISCOANALYSEUR TO :

METRAVIB
instruments

MEASUREMENT FILE...................... MVmxt1

DATE................................. 6/ 14/ 95

SAMPLE REFERENCE...................... MX 111 ACOUSTIC ISOL

TEST PERFORMED IN : TRACTION COMPRESSION

SAMPLE FEATURES :

- SHAPE..............................		PARALLELEPIPEDIC
- HEIGHT.............................	5.79	mm
- THICKNESS..........................	5.35	mm
- WIDTH..............................	4.72	mm

MEASUREMENT CONDITIONS :

- SCANNING IN TEMPERATURE.............	-40.1 -	40.0	oC
- SCANNING IN FREQUENCY...............	5.0 -	500.0	HERTZ
- REGULATION IN DISPLACEMENT..........		5.0	MICRON
- PRESTRAIN REGULATION................			NO

REMARKS :

TEST PERFORMED BY :

SERVICE :

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 1

- STARTING TEMPERATURE................ 24.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -40.1 oC

No	FREQUENCY HERTZ	E′ N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.755E+08	.226E+08	.788E+08	.299
2	54.5	.913E+08	.290E+08	.958E+08	.317
3	104.0	.896E+08	.315E+08	.950E+08	.351
4	153.6	.951E+08	.319E+08	.100E+09	.336
5	202.9	.101E+09	.323E+08	.106E+09	.319
6	252.5	.104E+09	.329E+08	.109E+09	.316
7	301.9	.106E+09	.336E+08	.112E+09	.316
8	351.1	.107E+09	.339E+08	.113E+09	.316
9	400.6	.105E+09	.338E+08	.111E+09	.321
10	451.3	.105E+09	.343E+08	.110E+09	.328
11	500.0	.100E+09	.362E+08	.106E+09	.362

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 2

- STARTING TEMPERATURE................. -40.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -30.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.477E+08	.161E+08	.504E+08	.337
2	54.5	.608E+08	.214E+08	.644E+08	.352
3	104.0	.594E+08	.234E+08	.638E+08	.394
4	153.6	.652E+08	.240E+08	.695E+08	.368
5	202.9	.697E+08	.247E+08	.740E+08	.355
6	252.5	.723E+08	.255E+08	.767E+08	.353
7	301.9	.740E+08	.261E+08	.785E+08	.353
8	351.1	.757E+08	.267E+08	.803E+08	.352
9	400.6	.765E+08	.272E+08	.812E+08	.356
10	451.3	.762E+08	.278E+08	.811E+08	.366
11	500.0	.748E+08	.305E+08	.807E+08	.407

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 3

- STARTING TEMPERATURE................ -30.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -20.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.372E+08	.131E+08	.394E+08	.353
2	54.5	.470E+08	.175E+08	.502E+08	.371
3	104.0	.487E+08	.188E+08	.522E+08	.386
4	153.6	.527E+08	.200E+08	.564E+08	.380
5	202.9	.560E+08	.206E+08	.597E+08	.367
6	252.5	.571E+08	.211E+08	.609E+08	.369
7	301.9	.586E+08	.216E+08	.624E+08	.368
8	351.1	.595E+08	.219E+08	.634E+08	.368
9	400.6	.606E+08	.225E+08	.646E+08	.371
10	451.3	.601E+08	.231E+08	.644E+08	.384
11	500.0	.582E+08	.256E+08	.636E+08	.439

SAMPLE REFERENCE...................... MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 4

- STARTING TEMPERATURE................ -20.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -10.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.296E+08	.105E+08	.314E+08	.355
2	54.5	.373E+08	.144E+08	.400E+08	.387
3	104.0	.407E+08	.160E+08	.437E+08	.394
4	153.6	.438E+08	.170E+08	.470E+08	.388
5	202.9	.463E+08	.174E+08	.495E+08	.375
6	252.5	.473E+08	.177E+08	.505E+08	.375
7	301.9	.484E+08	.182E+08	.517E+08	.375
8	351.1	.497E+08	.187E+08	.531E+08	.377
9	400.6	.499E+08	.190E+08	.534E+08	.381
10	451.3	.492E+08	.195E+08	.529E+08	.397
11	500.0	.469E+08	.218E+08	.518E+08	.465

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 5

- STARTING TEMPERATURE................ -10.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... .0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.236E+08	.852E+07	.251E+08	.361
2	54.5	.320E+08	.121E+08	.343E+08	.379
3	104.0	.341E+08	.135E+08	.367E+08	.395
4	153.6	.367E+08	.142E+08	.393E+08	.387
5	202.9	.388E+08	.146E+08	.415E+08	.375
6	252.5	.403E+08	.151E+08	.431E+08	.375
7	301.9	.413E+08	.155E+08	.441E+08	.376
8	351.1	.420E+08	.159E+08	.450E+08	.379
9	400.6	.423E+08	.162E+08	.453E+08	.384
10	451.3	.416E+08	.168E+08	.449E+08	.404
11	500.0	.390E+08	.190E+08	.434E+08	.487

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 6

- STARTING TEMPERATURE................ .0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 10.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.211E+08	.729E+07	.223E+08	.346
2	54.5	.262E+08	.102E+08	.281E+08	.388
3	104.0	.290E+08	.113E+08	.312E+08	.391
4	153.6	.319E+08	.122E+08	.342E+08	.381
5	202.9	.337E+08	.125E+08	.359E+08	.372
6	252.5	.348E+08	.129E+08	.371E+08	.371
7	301.9	.357E+08	.133E+08	.381E+08	.374
8	351.1	.363E+08	.137E+08	.388E+08	.378
9	400.6	.365E+08	.140E+08	.391E+08	.384
10	451.3	.355E+08	.144E+08	.384E+08	.406
11	500.0	.331E+08	.168E+08	.371E+08	.507

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 7

- STARTING TEMPERATURE............... 10.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 20.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.187E+08	.616E+07	.197E+08	.329
2	54.5	.238E+08	.891E+07	.254E+08	.375
3	104.0	.259E+08	.986E+07	.278E+08	.380
4	153.6	.282E+08	.105E+08	.301E+08	.374
5	202.9	.295E+08	.107E+08	.314E+08	.364
6	252.5	.305E+08	.112E+08	.325E+08	.366
7	301.9	.312E+08	.114E+08	.332E+08	.367
8	351.1	.318E+08	.119E+08	.340E+08	.373
9	400.6	.318E+08	.122E+08	.340E+08	.383
10	451.3	.308E+08	.125E+08	.332E+08	.408
11	500.0	.280E+08	.148E+08	.317E+08	.529

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 8

- STARTING TEMPERATURE................ 20.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 30.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.156E+08	.501E+07	.164E+08	.321
2	54.5	.204E+08	.746E+07	.217E+08	.365
3	104.0	.226E+08	.831E+07	.240E+08	.368
4	153.6	.245E+08	.890E+07	.261E+08	.363
5	202.9	.257E+08	.910E+07	.273E+08	.354
6	252.5	.267E+08	.951E+07	.283E+08	.356
7	301.9	.274E+08	.984E+07	.292E+08	.359
8	351.1	.278E+08	.101E+08	.296E+08	.364
9	400.6	.277E+08	.104E+08	.296E+08	.374
10	451.3	.264E+08	.108E+08	.286E+08	.410
11	500.0	.237E+08	.128E+08	.270E+08	.541

SAMPLE REFERENCE........................ MX 111 ACOUSTIC ISOL

TEMPERATURE NUMBER.................... 9

- STARTING TEMPERATURE................ 30.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 40.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.147E+08	.441E+07	.153E+08	.300
2	54.5	.177E+08	.637E+07	.188E+08	.361
3	104.0	.207E+08	.732E+07	.220E+08	.353
4	153.6	.223E+08	.780E+07	.236E+08	.350
5	202.9	.234E+08	.802E+07	.247E+08	.343
6	252.5	.242E+08	.838E+07	.256E+08	.346
7	301.9	.248E+08	.868E+07	.263E+08	.350
8	351.1	.251E+08	.894E+07	.267E+08	.355
9	400.6	.250E+08	.918E+07	.266E+08	.368
10	451.3	.237E+08	.955E+07	.256E+08	.402
11	500.0	.210E+08	.117E+08	.240E+08	.557